Non-uniform Copper Corrosion: Research Update

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Building a scientific foundation for sound environmental decisions

Installation, Condition Assessment, and Reliability of Service Lines, Connections and Fittings
AWWARF #2927

Project Summary:
Will identify parameters and conditions that influence the failure rate of service pipe materials, connections, and fittings. Will develop a best-practice manual based on extensive analysis of existing installation techniques and material types. Also will develop a methodology for assessing the life expectancy of service lines, connections, and fittings for different materials using a variety of installation techniques under varying environmental conditions.

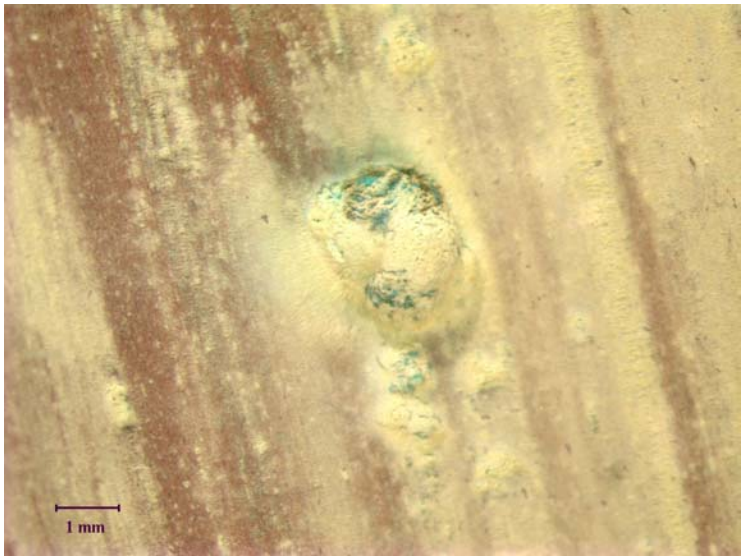
Overview of Copper Corrosion

- Uniform Corrosion Scale
- Erosion Corrosion
- Localized Corrosion (pitting)
  - Type I – Cold Water
  - Type II – Hot Water
  - Type II – Soft Water

Objective

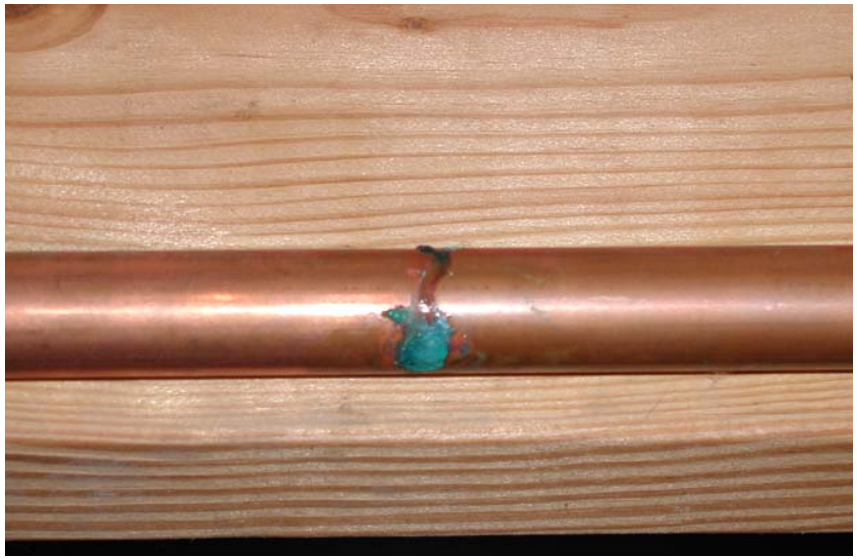
- Discuss approach to studying non-uniform copper corrosion
- Present findings

Localized Corrosion (Pitting)



Pitting is a localized acceleration of corrosion that results in the thinning of the pipe wall in the effected area.

Localized Corrosion (Pitting)



Localized Corrosion (Pitting)

- Type I – Cold Water Pitting
  - Attacks horizontal runs of cold water pipes in systems using well waters with a high sulfate to chloride ratio
- Type II – Hot Water Pitting
  - Occurs in hot water with a pH below 7.2
- Type III – Soft Water Pitting
  - Occurs in soft water above pH 8.0
- Microbiological, material defects

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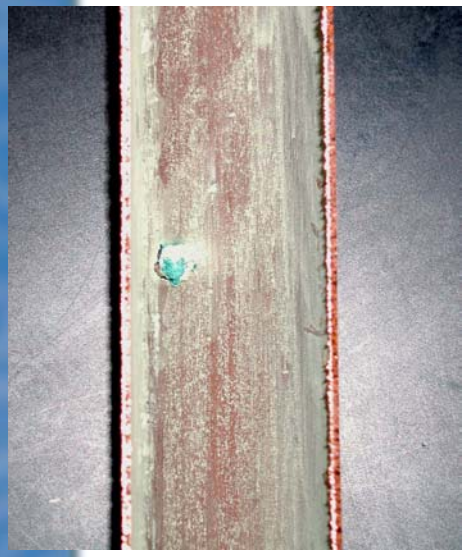
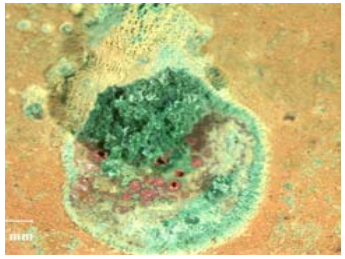
Pitting Comparison

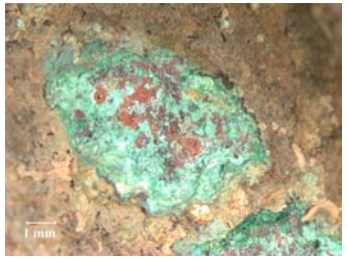


Ohio site #1

Wisconsin



Ohio site #2



All micrographs taken at 10x

Approach

- Field Observations
  - Survey Form- plumbing type, cold vs. hot, horizontal, etc..
- Solids Analysis
  - SEM, EDS, XRD, etc..
- Water Quality
  - Hot vs. cold, similar waters

Copper Pitting and the Consequences

- Costly Repairs
- Leaks may go undetected in walls or basements, and service lines
- Pinhole Leaks
  - Mold and Mildew
  - Liability Issues
- Does not lead to high copper levels at the tap

Pinhole Leaks

Pinhole leaks resulting from copper pitting

Case Study- Ohio Site 1

Field Observations

- Cold water
- Horizontal runs of pipe
- $\frac{3}{4}$" pipe
- Homes are about 7 years old
- Leaks occur near elbows and joints as well as in long runs
- No preference for the top or bottom of a pipe

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Case Study

Field Observations

¾" pipe

½" pipe

Elbows and joints

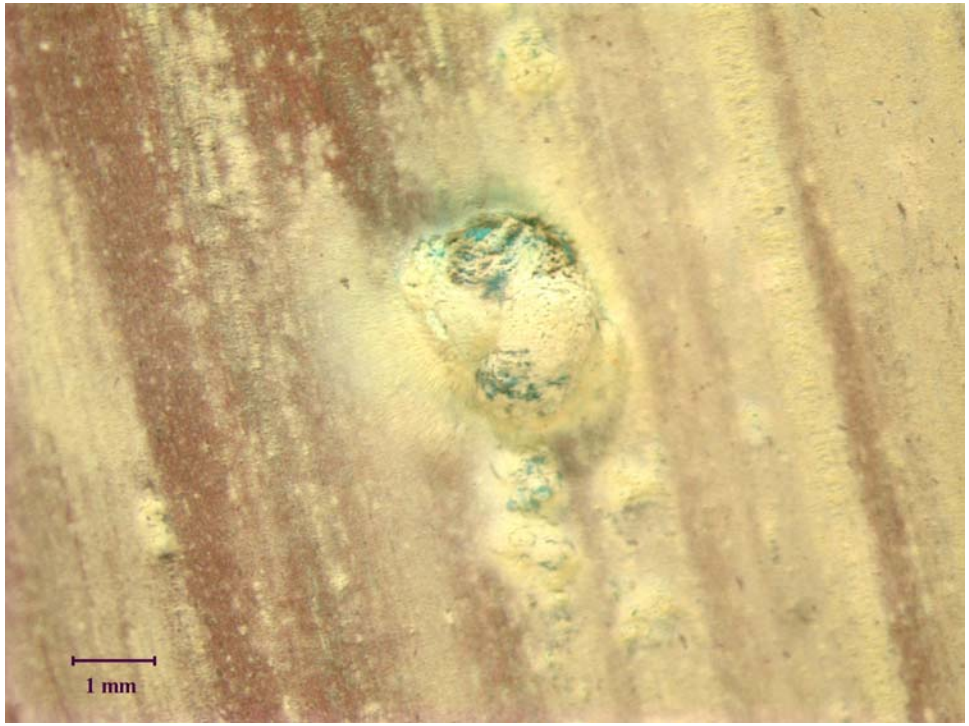
Water leaks

Pipe Cross-Section

Solids Analysis

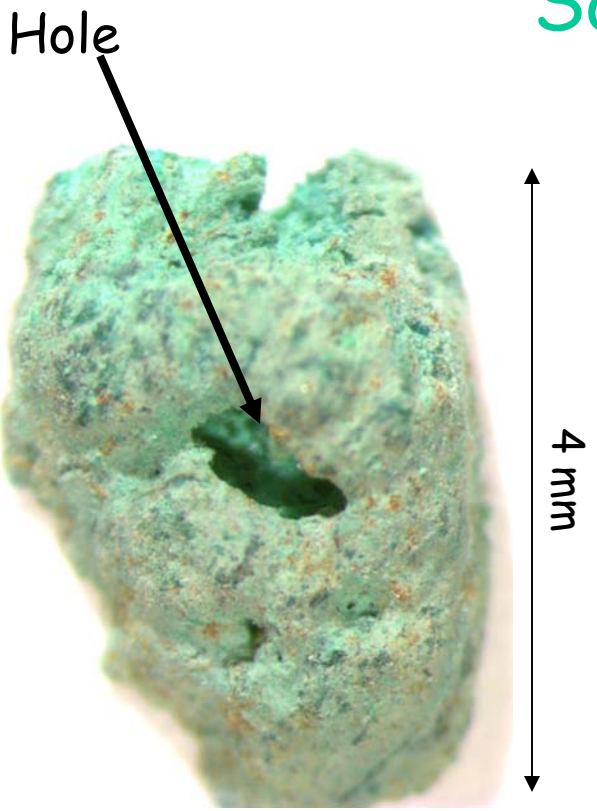
Anatomy of a Pit

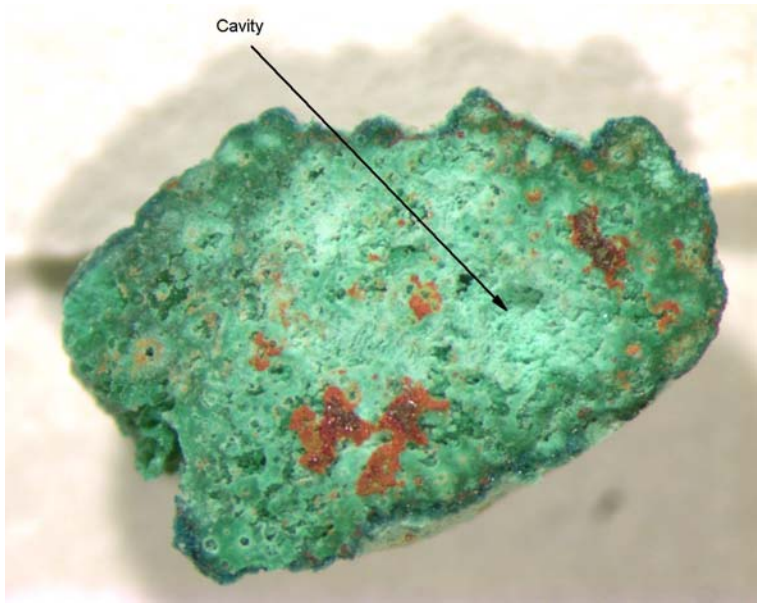
Solids Analysis



The Corrosion Cap

Solids Analysis





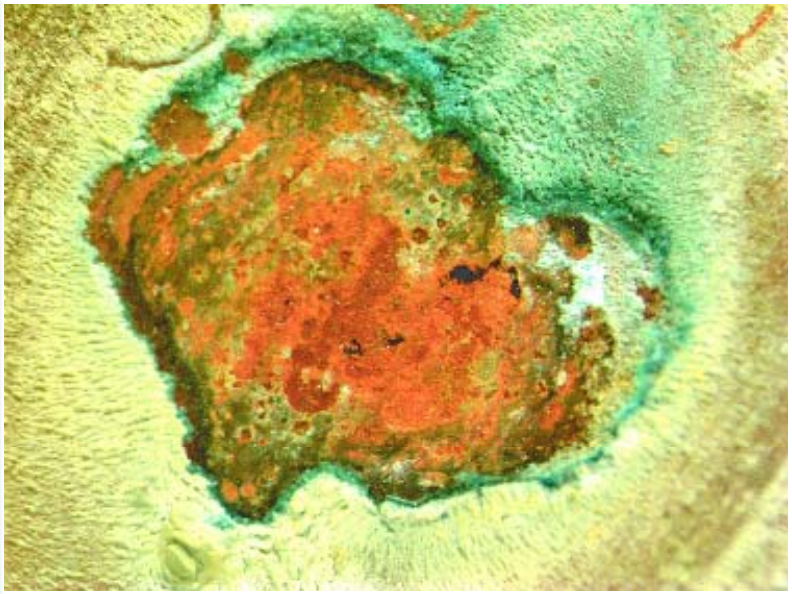
Cap Analysis

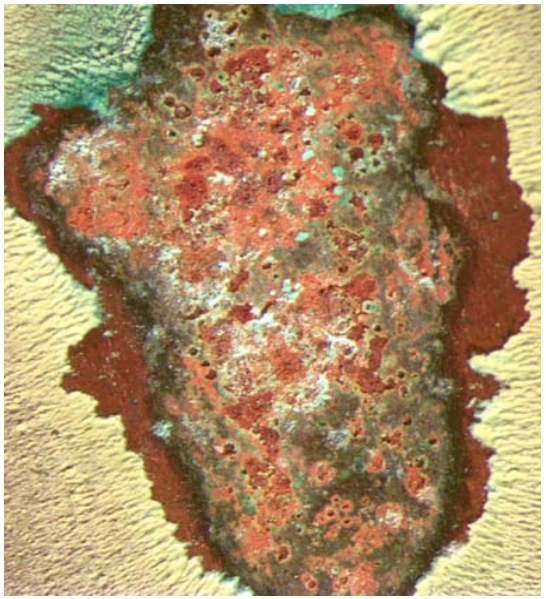
Solids Analysis

- Brochantite – $Cu_4(OH)_6(SO_4)$
- Ponsjakite – $Cu_4(OH)_6(SO_4)*H_2O$

Perforated Membrane

Solids Analysis

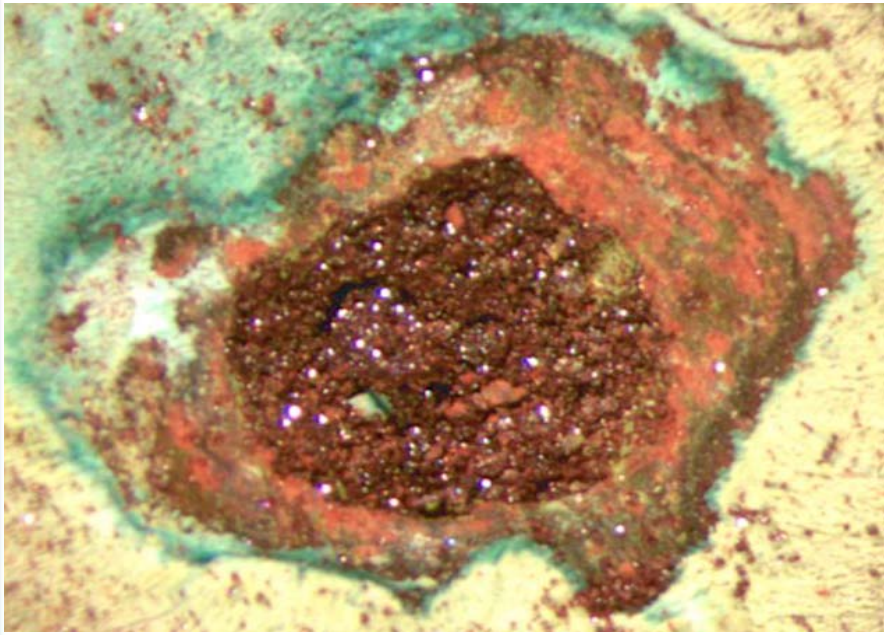


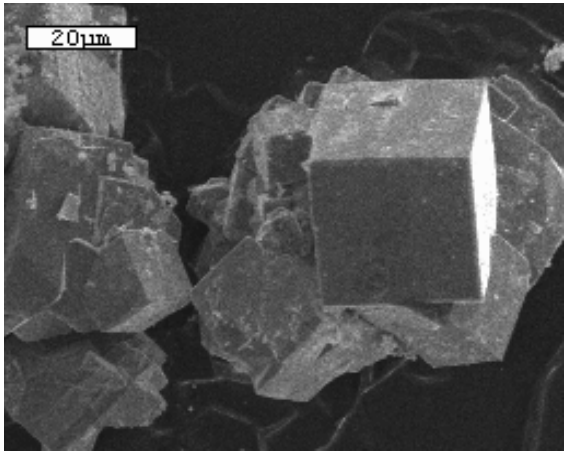


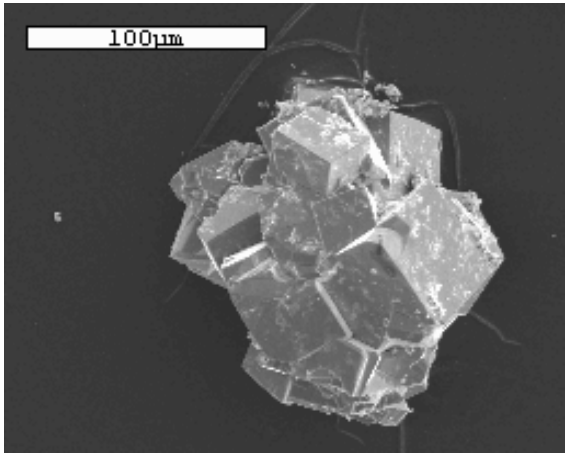
Literature suggests that the membrane consists of cuprite.

Breaking Through the Membrane

Solids Analysis

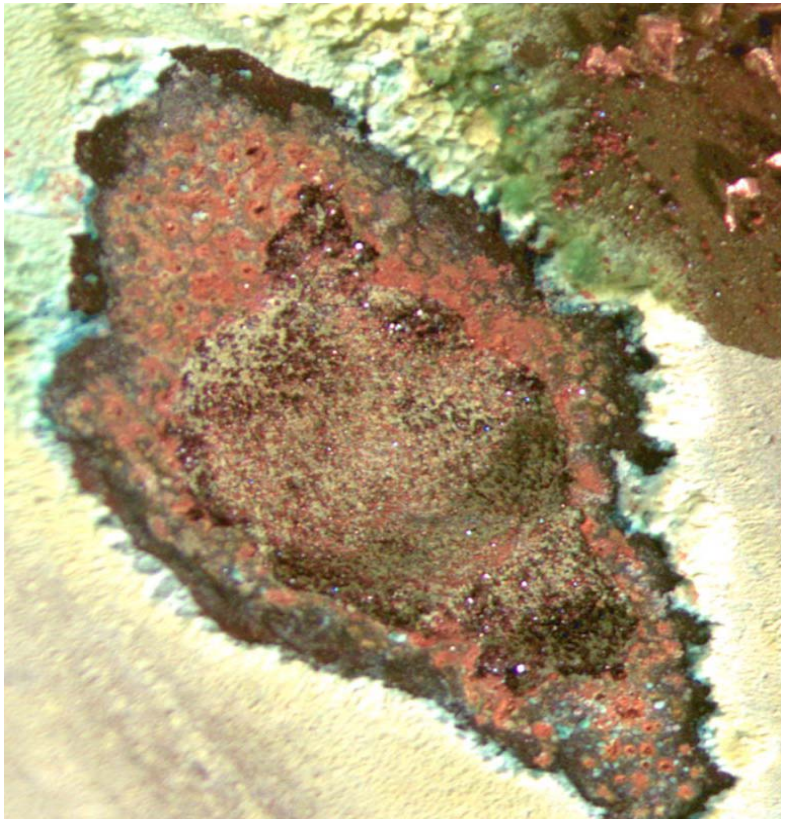




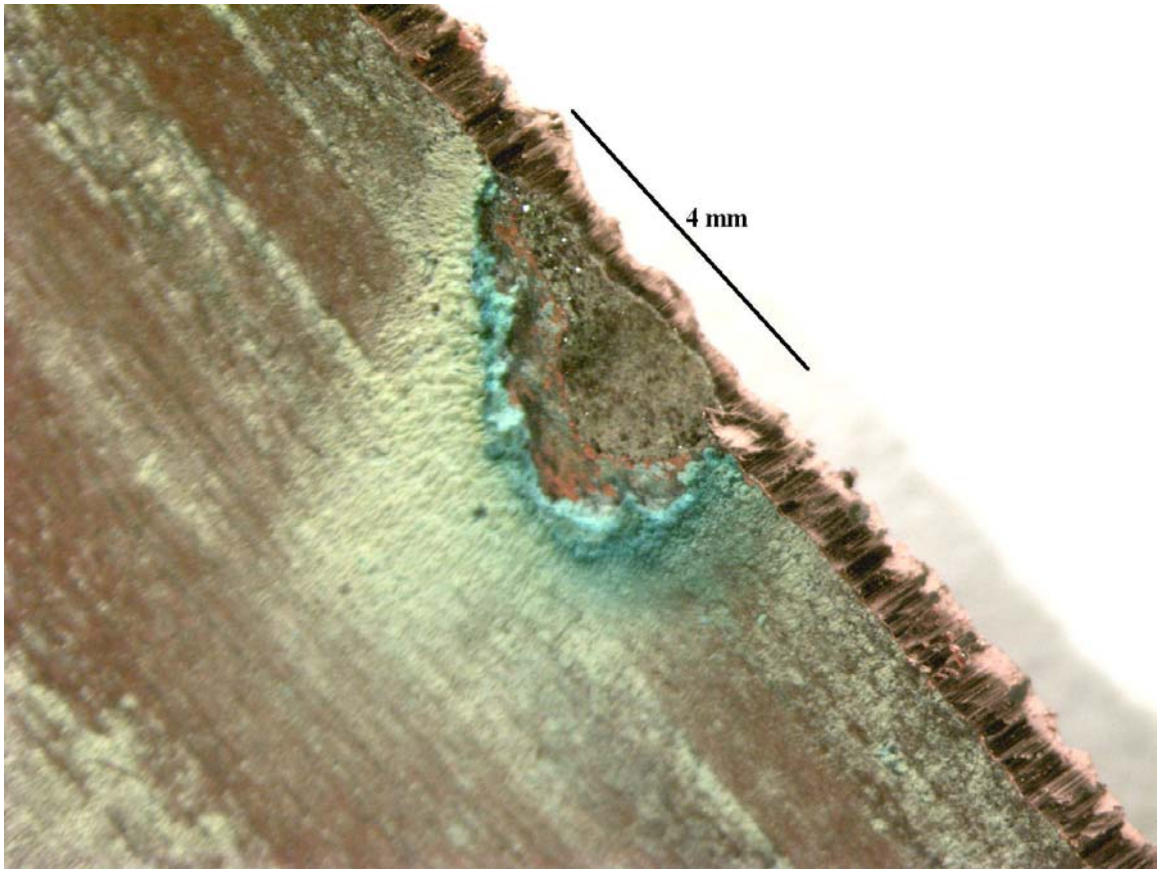


Pits are loosely packed with cuprite crystals beneath the permeable membrane

A Dissected Pit Reveals the Extent of the Damage

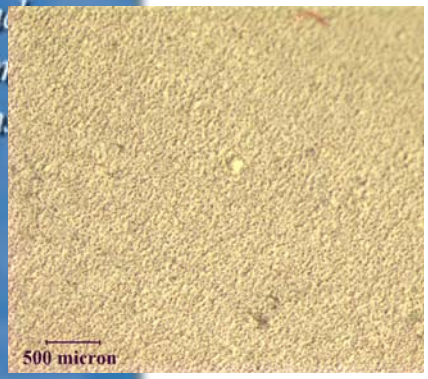


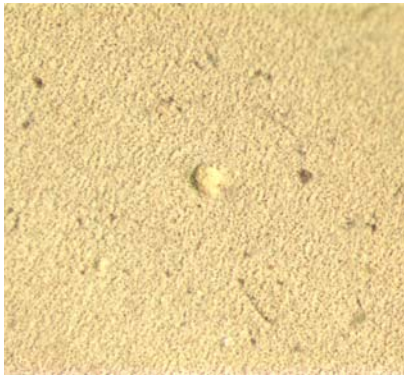
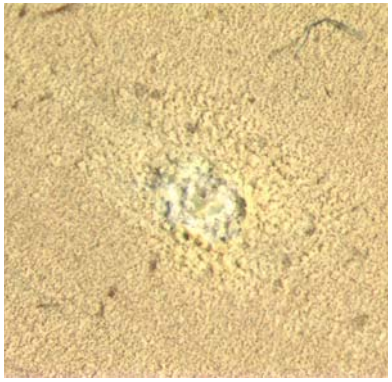
Cross-Section of a Pit



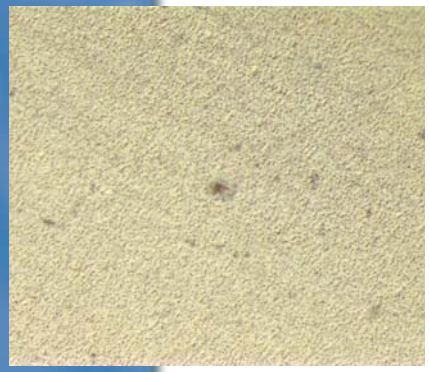
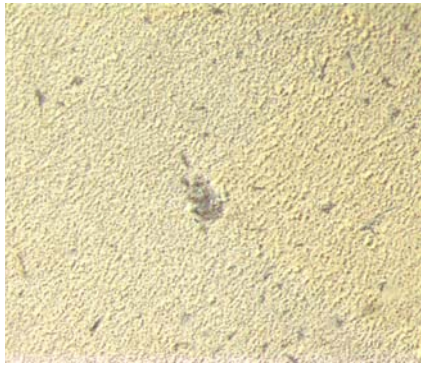
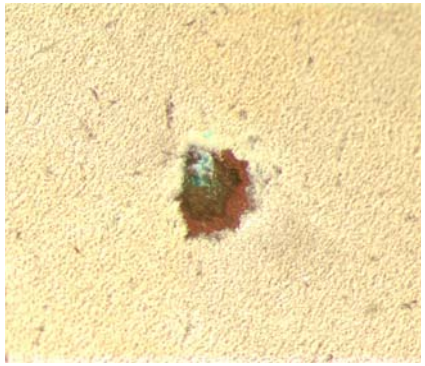
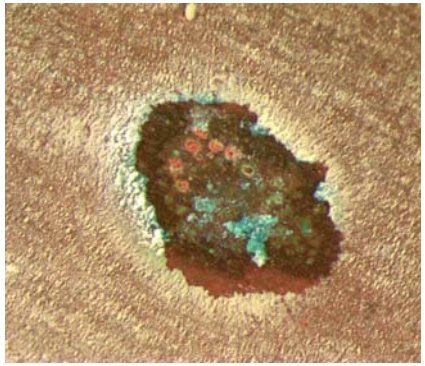
Pit Propagation

Theory



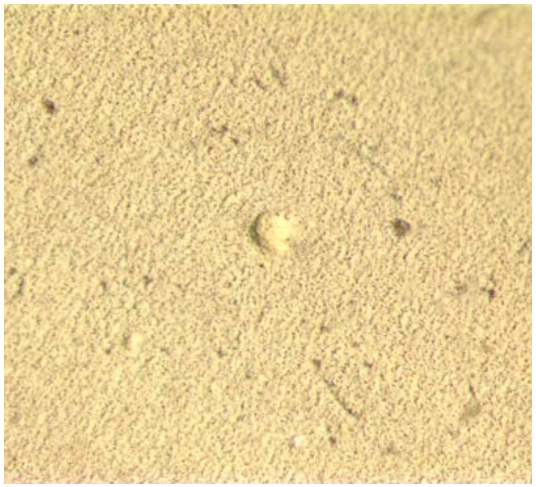

Particle deposition, particle growth, and corrosion cell formation

All pictures taken at same magnification

EDS Analysis of Particle

- Copper
- Aluminum
- Silicon
- Magnesium
- Oxygen



Water Chemistry Comparison

SAMPID	Ca, mg/L	Cl, mg/L	K, mg/L	Mg, mg/L	Na, mg/L	SO_4, mg/L	SiO_2, mg/L	TALK, mg/L $CaCO_3$	pH	TIC, mg C/L
Ohio Site #1	26.80	63.00	3.78	27.20	32.76	120.00	10.00	39.11	8.80	8.80
Bolton WTP	25.60	45.00	NA	23.70	NA	76.70	10.00	77.00	9.09	15.90

Future Work

- Survey individuals
- Contact plumbers and plumbing suppliers
- Examine more pipe
  - Carefully remove pipes
  - Microbiological analysis
- Water heater solids
- Sample distribution system water
- Cement Leaching Study
- Electrochemical corrosion analysis

Thank You